RCMES: A sustainable software tool for driving model evaluations and decision support in CORDEX communities

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I. Introduction

Climate models (global and regional) and observation data are necessary for informing decision-making processes related to climate impacts (Fig 1). As such, imbedded in the Coordinated Regional Downscaling Experiment (**CORDEX**; Giorgi *et al.* 2009) framework is the requirement to improve access to existing quality-assured long-term climate observations for the evaluation of regional climate projections.

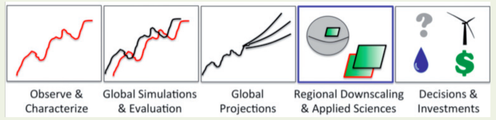


Figure 1: The process (from left to right) involved in a thorough informed decision making process. The blue box highlights where RCMES is involved in this process

The Regional Climate Model Evaluation System (**RCMES**, http://rcmes.jpl.nasa.gov/) developed collaboratively by NASA's Jet Propulsion Laboratory and the University of California, Los Angeles, inherently addresses this requirement. **RCMES** is a software tool designed to facilitate seamless, controlled end-to-end regional climate model (RCM) evaluation through access to a database (**RCMED**) inclusive of observation data, and a toolkit (**RCMET**) inclusive of capabilities for regridding, calculating evaluation metrics and visualizing data.

II. High-level Software Architecture

RCMES consists of two components: the Regional Climate Model Evaluation Database (**RCMED**) and the Regional Climate Model Evaluation Toolkit (**RCMET**). **RCMED** is a collection of PostgreSQL databases inclusive of NASA's remote sensing data - TRMM, AVISO, AIRS, and other observations - GPCP and reanalysis data such as CRU, that facilitates data classification, extraction and homogeneity, irrespective of the original data format e.g. NETCDF 3/4, GRIB, HDF 4/5, etc. (Mattmann et al. 2013). **RCMED** physically resides at JPL, and it easily accessible via **RCMES**. Box 1 indicates the datasets currently available in **RCMED**. Ahead of an evaluation, users may be required to load their data into **RCMED**. **RCMET** provides the capabilities of regridding, calculating evaluation metrics e.g. RMS, bias and correlation coefficients, and visualizations of the data. **RCMET**'s flexibility allows users to (1) change the workflow of an end-to-end evaluation, (2) supplement with their metrics, and (3) extract data during the evaluation.

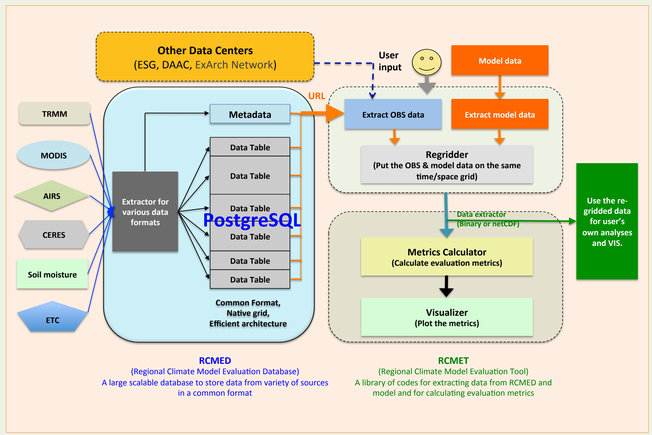


Figure 2: Schematic of RCMES

The **RCMET** and the data transfer components of **RCMED** have been donated to the Apache Foundation through the Open Climate Workbench project (**Apache OCW**, http://climate.incubator.apache.org/). **Apache OCW** maintains the high-level functionality of **RCMES**, but allows the user greater flexibility in creating individual project workflow. In general, **Apache OCW** allows users to build other applications that require the underlying functionality of data extraction, manipulation, calculations, and visualization. **RCMES** is an example of such an application. **Apache OCW** is currently incubating at Apache, which is not a reflection of the completeness of the code, but rather a statement regarding the endorsement process of the Apache Software Foundation (ASF).

Box 1: Datasets available in RCMED

Dataset Name	Abbreviation	Variables	Description
NCEP CPC Rain gauge analysis	CPC	Precipitation	Precipitation variable within the Unified Rain-gauge Database at 0.25° resolution. Daily and monthly data.
AIRS L3 Standard daily product (AIRS/AMSU) Version 5	AIRS	Surface air temperature; atmospheric temperature; geopotential height	Daily gridded standard retrieval product using AIRS IR and AMSU, without-HSB
Tropical Rainfall Measuring Mission Dataset	TRMM	Precipitation	The TRMM standard products include measurements from satellite and ground-based sensors and geophysical parameters derived from them. Daily and monthly data.
NCEP North American Regional Reanalysis	NARR		NCEP North American Regional Reanalysis at 0.3° resolution.
Climate Research Unit TS 3.1 Dataset	CRU_TS_3.1	Precipitation; daily-mean; max and min surface air temperature	Gridded analysis of surface station observation over the global land surfaces at 0.5° resolution. Daily and monthly data.
Climate Research Unit TS 3.0 Dataset	CRU	Precipitation; daily-mean; max and min surface air temperature	Updated version of the CRU 3.0 data. Daily and monthly data
ERA-Interim Reanalysis	ERA	Temperature; dew-point; temperature; geopotential height	Global reanalysis product from ECMWF. Daily and monthly data.
Moderate Resolution Imaging Spectro-radiometer	MODIS	Cloudiness	Satellite-based retrievals. Daily and monthly data.
Sierra Nevada Snow-water equivalent	SWE	Snow-water equivalent	Blended satellite retrieval and surface observations over the Sierra Nevada range. Monthly data.
MERRA DAS3d analyzed state on pressure	MAI6NPANA	MSLP; Surface pressure	NASA-GMAO Global Reanalysis Monthly data
CERES Radiation	CERES	Short- and longwave irradiances for all sky, clear sky, TOA, and surface	Satellite retrieved radiation product. Monthly data.
GCPC Version 2.2 Combined Precipitation Dataset	GPCP	Precipitation	Composite precipitation product. Monthly data.
AMSRE	AMSRE	Sea Surface temperature	Sea Surface Temperature from AMSR-E onboard AQUA
University of Delaware Air Temperature & Precipitation	UofDelaware_Temp_Precip	Precipitation; temperature	Monthly global gridded high resolution station (land) data for air temperature and precipitation from 1900-2010

III. Using RCMES

RCMES seeks to provide a tool that can be applied without pre-defined approaches, and is intended to appeal to users with diverse computer and climate skill through various interfaces such as a web-based interface and a command-line interface. **Apache OCW** drives the **RCMES** web interface.

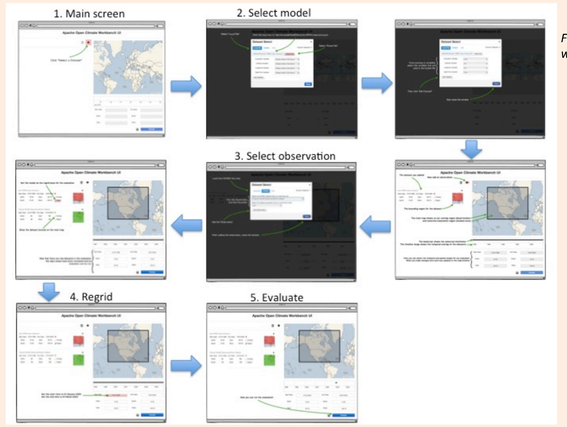
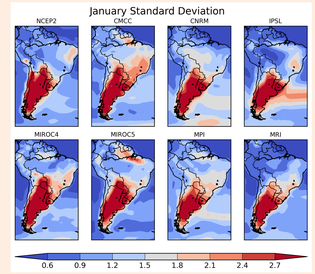


Figure 3: Screenshots of the workflow of the web-based interface

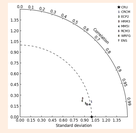
V. RCMES, OCW and the community

RCMES and **Apache OCW** are being used in regional projects involving CORDEX, such as CORDEX-Africa, CORDEX-India and CORDEX- N. America i.e. NARCAPP for model evaluation, data management, and metrics and visualization tool in research and assessments (e.g. Kim *et al.* 2013, Loikith *et al.* 2013).

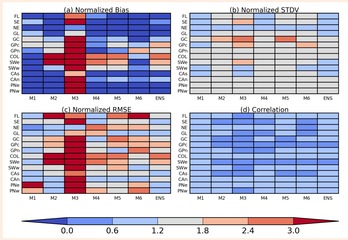
Box 2: Examples of metrics and visualizations in RCMES



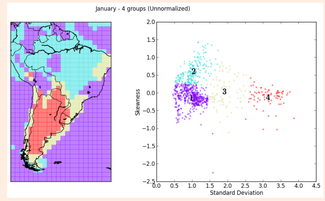
Contour maps representing standard deviation of daily surface air temperatures in January((1981-2000) for NCEP2 reanalysis and seven CMIP5 GCMs.



Taylor diagram representing the simulated normalized annual-mean surface air temperature w.r.t. CRU for 1980 – 2003. Taken from Kim *et al.* 2013 Fig 6



Portrait diagram of regional bias, temporal standard deviation, RMSE and temporal correlation coefficients of model surface temperatures w.r.t. CRU in summer JJA 1980 – 2003. Taken from Kim *et al.* 2013 Fig 7



K-means clustering s applied to partition grid points into four groups according to the standard deviation and skewness of temperature probability density function.

VI. Future work

The next steps for **RCMES** and **Apache OCW** include: (1) continuous upgrades of **RCMED** regarding data ingestion and extraction to facilitate model evaluations and decision support systems; (2)upgrades to **RCMET** including additional methods and metrics for statistically qualifying the robustness of results; (3) spatial-temporal analysis capabilities; (4) promoting greater use of **RCMES** and **Apache OCW** in regional activities.

VII. Acknowledgements

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VIII. References

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